Argonian (γ Argûs).—H, p H.

Alnitamian (ε Orionis).—H, He, λ4649, Si IV.

Proto-metallic lines relatively thick, hydrogen relatively thin.		Proto-metallic lines relatively thin, hydrogen relatively thick.
Crucian (α Crucis).—H, He, Ast, O, N, C.	*Achernian* (α Eridani).—Same as Crucian.	
Taurian (ζ Tauri).—H, He, p Mg, Ast.	*Algolian* (β Persei).—H, p Mg, p Ca, He, Si II.	
Rigelian (β Orionis).—H, p Ca, p Mg, He, Si II.	*Markabian* (α Pegasi).—H, p Ca, p Mg, Si II.	
Cygnian (α Cygni).—H, p Ca, p Mg, p Fe, Si II., p Ti, p Cr.	*Sirian* (α Canis Maj.).—H, p Ca, p Mg, p Fe, Si II.	
Polarian (α Urs. Min.).—p Ca, p Ti, H, p Mg, p Fe, Ca, Fe, Mn, Si I.	*Procyonian* (α Canis Min.).—Same as Polarian.	
Aldebarian (α Tauri).—p Ca, Fe, Ca, Mn, p Sr, H, Si I.	*Arcturian* (α Boötis).—Same as Aldebarian (includes the Sun).	
Antarian (α Scorpionis).—Flutings of manganese,[1] and many metallic lines.	*Piscian* (19 Piscium).—Flutings of carbon and many metallic lines.	
[Nebulæ.]	[Dark Stars.]	

[1] Many of the flutings have since been shown to be due to titanium [Fowler, Roy. Soc. *Proc.*, vol. lxxiii. p. 219 (1904)]. The flutings are most strongly developed in the less refrangible parts of the spectrum, and are not seen in the spectrum of Betelgeuse reproduced in Fig. 4.

Examples illustrating most of the groups are given in Figs. 4 and 5, from negatives taken by Sir Norman Lockyer and his assistants at the Solar Physics Observatory. These are to appear coloured are represented by diffraction gratings of various spacings. A grating ruled on glass, when combined with a convex lens and directed towards a lamp flame or other source of light, forms diffraction spectra in the focal plane of the lens. If the pupil of the eye is brought into the red portion of one of these spectra, we perceive the entire surface of the grating illuminated in red light, since every portion sends red light, and red light only, into the eye. If a second grating with closer ruling is substituted for the first, the eye remaining fixed in position, the spectra will occupy different positions, and if the pupil of the eye occupies, say, the green region of one of them, this grating will appear green. If the two gratings are placed side by side, and overlapping one another, the one will appear red, the other green, while the overlapping region, since it sends both red and green light to the eye, appears yellow (secondary yellow). If a third grating of still finer spacing is now placed before the lens, partly overlapping the other two, it will appear illuminated in blue-violet light, and the overlapping portions will be coloured purple, white, and bluish-green.

We may in this way obtain a large variety of colour with only three rulings, and since the intensity of the light depends on the distinctness with which the lines are ruled or photographed, light and shadow can be obtained solely

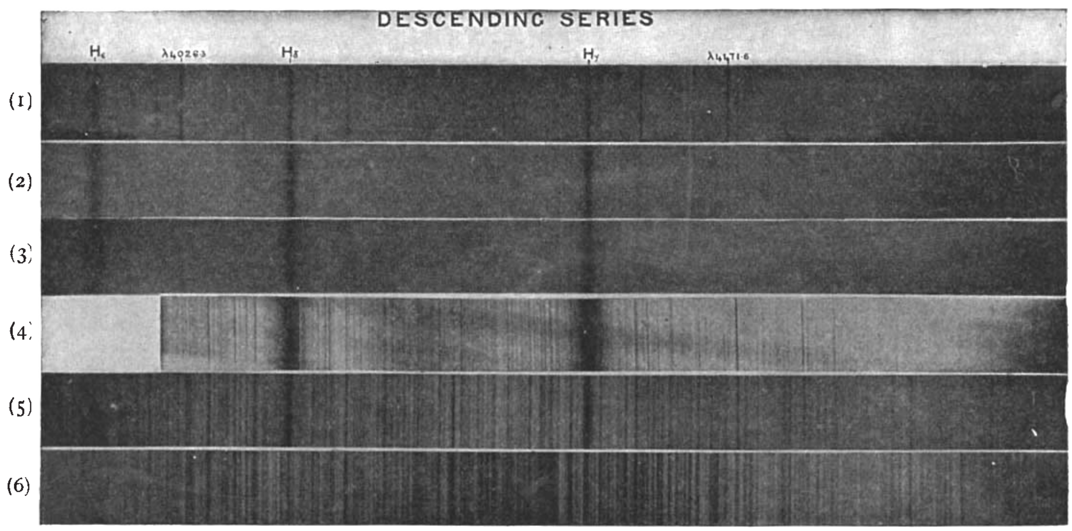

Fig 5.—Stars of decreasing temperature:—(1) γ Orionis (Crucian); (2) β Persei (Algolian); (3) α Pegasi (Markabian); (4) α Canis Majoris (Sirian); (5) α Canis Minoris (Procyonian); (6) α Boötis (Arcturian).

bring out very clearly the gradual simplification of the spectrum in the first series as the temperature rises, and the increasing complexity in the second series as the temperature falls. On the dissociation hypothesis, we have first to deal chiefly with relatively cool metallic vapours, which, as the temperature rises, are brought by *dissociation* to the proto-metallic stage, and finally to the gaseous condition represented by hydrogen and helium; then, through subsequent cooling, *association* begins and produces somewhat similar changes in inverse order.

A. Fowler.

RECENT IMPROVEMENTS IN THE DIFFRACTION PROCESS OF COLOUR-PHOTOGRAPHY.[1]

The fundamental principles of the diffraction process of colour-photography will be found in my earlier papers on the subject.[2] In brief, the method consists in preparing by photographic means a picture in which the areas which by the presence of the diffracting lines. The portions of the plate on which they are absent send no light to the eye, and appear black.

A full description of the method by which photographs showing the colours of the original object were prepared will be found in the papers above referred to.

The earlier experiments were made with very imperfect gratings, the periodic errors of which caused the pictures to show vertical bands of colour. During the past winter I have ruled gratings of various description on one of the Rowland engines, and continued the experiments of five years ago.

This machine was designed to rule 14,438 lines to the inch, but by employing larger cams, which cause the pawl to skip a specified number of teeth, it may be made to rule at the rate of 7219, 4812, 3609, and so on. Calculations showed that gratings ruled on this machine with cams which advanced the toothed rim of the large wheel five, six, and seven teeth respectively would be suitable, that is, would have the relative spacings necessary to produce white when they were superposed.

To illustrate the principle of the colour synthesis, a glass plate was ruled with the three spacings, the ruled squares overlapping as shown in Fig. 1*a*. The areas appeared coloured as indicated when the plate was placed in front

[1] Paper read before Section A of the British Association at the Cambridge meeting by Prof. R. W. Wood.

[2] Wood, "Application of the Diffraction Grating to Colour-photography" (*Phil. Mag.*, April, 1899); "Diffraction Process of Colour-photography," (Nature, vol. lx. p. 199, 1899).

of the viewing lens. The white area in the centre was of good quality, though not quite so bright as in the photographic gratings, for the reason that the three sets of rulings were rather more than the glass surface would take without breaking down between the lines. Photographic copies of this multiple ruling have been made, and will probably prove useful in demonstrating colour synthesis.

The appearance of two overlapping rulings under the microscope is shown in Fig. 1*b*.

It would appear at first sight as if a ruling of this description would be incapable of giving distinct spectra, and we should certainly not expect it to give merely the superposed spectra of the two gratings.

As a matter of fact, secondary spectra are produced, though they are usually so faint that they give no trouble. In some cases, however, owing to some peculiarity of the form of the groove, the photographic copies when superposed do not give the expected colour. For example, in one exceptionally pronounced case, the superposition of the red and violet gratings gave, instead of purple, a brilliant yellow-green.

The origin of the secondary spectra can be seen in the following way. If the red and violet gratings are superposed with the lines mutually perpendicular, and a lamp is viewed through the combination, the spectra appear as in

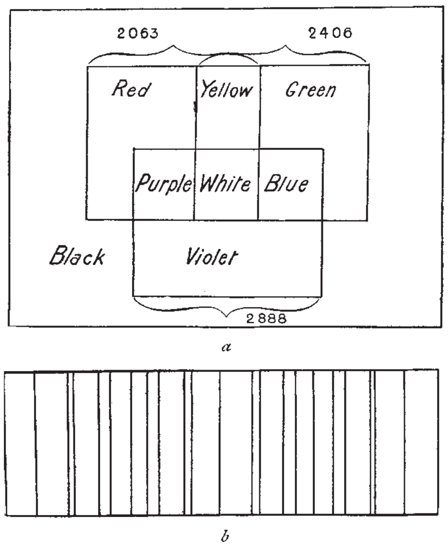

FIG. 1.

Fig. 2, the secondary spectra being usually much fainter than the principal ones. If, now, one of the gratings is slowly rotated through a right angle, the spectra will gradually wheel around into a straight line, and the secondary spectra will be found to fall *between* the principal spectra. In the particular case alluded to above, the secondary spectra for some reason or other were brighter than the principal, and it was found that the yellow-green of one of them fell at the point where the red and violet of two of the principal spectra coincided. This accounted for the abnormal colour which appeared in this case. It is very seldom, however, that these abnormal colours appear in the pictures.

A set of gratings for the production of colour photographs was ruled on this machine, and results far superior to any that had ever been obtained before were immediately secured. A few of the pictures were of such excellence as to compare favourably with the results obtained in the Kromshop. The method of preparing the pictures was essentially as I have described in previous papers.

The diffraction process has also been successfully combined with the Joly process. To accomplish this it was necessary to rule the three sets of lines in bands corresponding to the width of the red, green, and blue lines of the Joly screen. Calculation showed that if 12 lines were ruled with the 5-tooth cam, 10 with the 6-tooth, and 9 with the 5-tooth, the spaces would be about right.

Various schemes for making a ruling of this description were considered, but no satisfactory automatic device appeared to be possible, since the period of the bands on the Joly screen could not be exactly duplicated by any combination of cams.

The following simple device was finally hit upon. The engine was equipped with the 7-tooth cam, and a small stepped piece of brass mounted under the lever which operated the pawl, which, by preventing the complete descent of the lever, caused an advance of only 6 teeth or 5 teeth according to its position. The Joly screen was mounted on the table of the engine under a microscope, and the transit of the coloured lines across the × hair in the eye-piece observed, the rate of the ruling being changed at the proper moment by sliding the stepped piece of brass into the proper position, which was done by means of a short brass rod. The ruling of the grating occupied twelve hours, during which time I was obliged to sit with my eye constantly at the microscope, for the change of rate occurred about every half minute. Two very satisfactory gratings were prepared in this way, one corresponding to the Joly screen and the other to one of the screens ruled on the machine of the McDonough Co., of Chicago.

These gratings when placed in the viewing apparatus appeared white and very brilliant, and were easily duplicated by photography.

They were used in the following way:—

A positive on glass, made from a Joly negative, was flowed with a thin solution of gelatin sensitised with

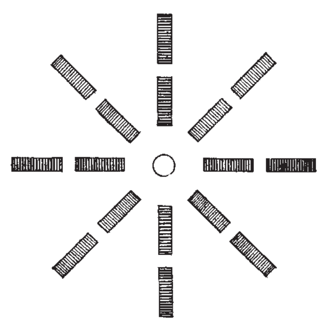

FIG. 2.

bichromate of potash, and allowed to dry. The triple ruled grating was then placed with its ruled surface in contact with the sensitive film, and held before the lens of the viewing apparatus. The appearance of the picture was now precisely similar to the appearance when a Joly colour screen was used, and the lines could be brought into register at once, when the picture appeared in its natural colours. A ten-second exposure to the light of the arc recorded the grating lines on the film, and the plate was then dipped into warm water and dried. The colours of the picture prepared in this way were fully equal, if not superior, to those obtained with the Joly viewing screen. There is the added advantage that the colour lines and picture lines are on one and the same film, consequently there is no liability of the lines to get out of register. Moreover, the picture can be duplicated by contact printing on glass sensitised with chrom-gelatin. These prints are, of course, quite transparent until they are placed in the viewing apparatus, when the coloured picture at once appears.

By this means the trichromatic screen, which in the Joly process must be mounted with every picture, is done away with, and a picture obtained which can be easily duplicated. To offset the advantages gained we have, however, the disadvantage that the pictures require the viewing apparatus, and show the same obtrusive lines as the original Joly pictures. The triple diffraction screen could easily be ruled with its colour elements much closer together, but we should gain nothing in this way until some method of taking a negative with narrower colour elements is devised.

The pictures made by the old method with three separate

gratings can, I believe, be very much improved, as soon as some better method of printing gratings is devised. I have worked exclusively with chrom-gelatin, and it is by no means easy to get a film of such uniform thickness that the print made on it appears uniformly illuminated.

During the past summer I made some experiments with Prof. Lippmann, of Paris, on copying gratings by means of the plates which he uses in his process of colour-photography. These plates are much more sensitive than chrom-gelatin plates, are orthochromatic, and yield gratings of great brilliancy and uniformity. Whether they are capable of receiving two or more impressions remains to be seen. If they are it will probably be possible to form a diffraction colour-photograph directly in the camera, in the manner suggested in one of my earlier papers.

Moreover, if the triple ruling can be transferred in any way to the Joly taking screen, it is obvious that the *negative* taken by means of it in the camera will, when placed in the viewing apparatus, appear as a positive in natural colours; we can thus obtain our coloured positive at once in the camera, and make as many duplicates from it as we please by contact printing.

THE AGRICULTURAL EDUCATION CONFERENCE AT GLOUCESTER.

UNDER the auspices of the Gloucestershire County Council, a conference on agricultural education was held at the Shire Hall, Gloucester, on October 15. There was a large attendance not only of those locally interested in either education or agriculture, but also of delegates from many of the other counties. After a few preliminary remarks from the chairman, Sir John Dorington, Lord Onslow opened the proceedings, and explained the work his department was charged with in regard to education. He justified the retention of that work by the Board of Agriculture instead of allowing it to be merged in the general educational system administered by the Board of Education, on the plea that agriculture in England was so far from being the leading industry that the specialised education it required would get scant attention were there not his own department peculiarly interested in fostering it. He claimed that the constant and sympathetic communication between the two departments secured more favourable results than could be acquired under the Board of Education exclusively. The work of the Board of Agriculture was confined to assisting the collegiate centres under which the greater part of the country was now grouped; there was, however, a large blank on the educational map, for the whole of the west country, including Gloucestershire itself, had no centre of university rank from which agricultural instruction emanated. He trusted that the present conference would pave the way towards remedying the need he had indicated.

Sir William Hart-Dyke, to whom the first paper, on higher agricultural education, had been entrusted, was unable to be present; his paper, of which an abstract was read, warned the meeting of the difficulty that now confronted all counties in the matter of higher education because of the great draft on their funds for the future training of elementary schoolmasters.

A paper by Prof. Middleton, of Cambridge University, next dealt with the proper function of experimental plots in local agricultural education; Prof. Percival, of Reading, who followed, dealt with the ideal course of instruction in an agricultural college. The current courses, he maintained, were far too scientific; chemistry, botany and kindred sciences should be reduced to a minimum in favour of work on the farm, a thoroughly popular programme which appealed to the "practical men" in the room.

Lord Monteagle then opened the second part of the proceedings, on the education of the small farmer, with an account of the way the Irish Board of Agriculture had gone to work.

In Ireland the central authority administered the larger part of the funds, contributing five-ninths of the cost of any work, and securing four-ninths from the local authority; thus the organisation proceeded more evenly over the whole country than in England, where the initiative rests with the local authority. Next, they had proceeded in Ireland on the principle of establishing no institution until they had created a demand for it by means of pioneer lecturing and demonstrations. Lastly, in Ireland they believed that the industrial organisation of the farmers must go hand in hand with their education.

Prof. Wallace, of Edinburgh, who followed, dwelt on the necessity of beginning an agricultural training at an early age, so far as practical work on the farm went, leaving the true technical instruction to come when the lad had matured. Mr. Frederick Verney also dwelt on the harm that was being done to country children by keeping them at unsuitable school subjects until they had lost all taste for farming pursuits; the present system of elementary education contributed both to the depopulation of the country and the overcrowding of the towns.

Mr. H. Hobhouse, M.P., spoke on the value of attaching agricultural sides to the ordinary country grammar schools; the training would not be technical, but scientific with an agricultural bias.

After lunch Mr. Morant expressed his pleasure at the opportunity the conference afforded him of learning the feelings of the great agricultural community towards the educational system of the country. He assured the meeting that the Board of Education was wholly anxious to assist, provided the men who represented agriculture on such occasions would make their views precise, and, instead of grumbling at large, would indicate exactly what worked harshly or harmfully in the present arrangements controlled by the Board of Education.

A paper by Sir C. Dyke Acland was then read in his absence; it dealt with the education of the labourer, and was, like so many that followed, a plea for more intelligent teaching in our elementary schools, and for a more flexible system which would partially liberate boys at an earlier age for light work on the farm. Mr. G. Lambert, M.P., and Mr. Martin F. Sutton emphasised this point of view, and, like Mr. Acland, they agreed that in the main rural labour difficulties had been caused by keeping the rate of wages too low, with consequent loss of efficiency.

The last section of the conference, on the education of the teacher and expert, was opened by Mr. A. D. Hall, who pleaded for a more rigorous training which should include some experience in farming for the teacher of agriculture, and some work at research for the man who dealt with agricultural science. Canon Steward, principal of the Salisbury Training College, discussed more generally the education of the elementary schoolmaster and mistress in country districts, and finally, Mr. R. P. Ward gave an account of the way the teachers were being trained in Cheshire.

In the discussion which followed most of the speakers urged the substitution of winter schools or of evening continuation schools for the compulsory attendance of country boys at school up to the age of fourteen; for farming purposes a boy ought to begin light work on the farm at the age of twelve at latest, though his education should go on much later than it does now.

The conference was noteworthy not only for the quality of the papers read, but for the advance they showed in the direction of organisation on those submitted to previous conferences. It was made clear that there are several different classes to be provided for; the large farmer's son or future land agent wants a different equipment from that of the small holder; the farmer himself must be reached by an entirely different method; the labourer, again, has to be treated separately. At Gloucester the various speakers defined clearly their aim and their method; in former gatherings of the same nature the speakers seemed to consider there was only one kind of worker engaged in agriculture.

THE SPREAD OF PLAGUE.[1]

IN accordance with our views on the origin of epidemics it is necessary to believe that the plague which appeared in Bombay in the autumn of 1896 was derived from some previously infected locality. Two such localities have been

[1] Substance of a paper read before the Section of Physiology at the Cambridge meeting of the British Association on August 19 by Dr. E. H. Hankin.